In addition to the discussion with builders of military ships, RAND investigated innovative commercial construction techniques that may lead to reduced carrier-construction costs. Of the commercial shipyards we could have studied, we focused on those building large cruise ships, because such ships are the most like aircraft carriers in size, electrical loads, and habitability (berthing, laundry, food service, waste handling and disposal, medical and dental support services, etc.).

In an industry experiencing overcapacity and generally low price levels, only a few commercial cruise-ship builders have succeeded. This appendix documents discussions with Kvaerner Masa in Helsinki.

**ORGANIZATION AND PRODUCT**

Kvaerner Masa-Yards is a Finnish shipbuilding company formerly owned by Wartsilla, a diesel-engine manufacturer, and acquired by Kvaerner A.S. in 1990. It builds cruise liners and passenger ferries, gas carriers, and ice breakers, as well as all types of special-technology vessels, such as special tankers, cable ships, research vessels, vessels for the offshore oil and gas industry, dredgers and cranes, and heavy-lift ships.\(^1\) The company, which employs 4,900 people, has been a part of the Shipbuilding Division of the international industrial Kvaerner A.S. group since 1991. Kvaerner is headquartered in London. Other major divisions are

- the Kvaerner Masa-Yard Piikkiö Works, which is a factory producing prefabricated cabin and bathroom modules

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\(^1\)Kvaerner Masa-Yards and Kvaerner Masa Marine Inc., a subsidiary operating out of Annapolis, Maryland, are providing design and engineering for the 30,000-s.h.p. (shaft horsepower) Polar Icebreaker Healy, under construction at Avondale Industries Inc. for the U.S. Coast Guard.
• Kvaerner Masa-Azipod, which is responsible for the development, production, and sales of electric azimuthing Azipod propulsion drives²

• Kvaerner Masa-Yards Technology, which covers R&D, concept design and engineering services, and shipyard and welding technology, and includes the Arctic Technology Center (MARC) in Helsinki and the Welding Technology unit in Turku

• Kvaerner Masa Marine Inc., Vancouver, British Columbia, and its affiliate company Kvaerner Masa Marine Inc., Annapolis, Maryland, which are engaged in marine consulting engineering and marketing in North America.

Kvaerner Masa-Yards Inc. operates two new shipbuilding yards—Turku New Shipyard and Helsinki New Shipyard. Each yard is complete and independent: Each does its own design, engineering, and building, but the workload can be balanced between yards to ensure efficient workloading and profitability. Kvaerner Masa-Yards is in new-ship building only. Each had a repair capability but shed it because they are located out of the mainstream of ship traffic and because the Helsinki harbor is iced over during the winter months.

Kvaerner Masa-Yards' Helsinki New Shipyard is building the largest series of cruise ships ever ordered: eight ships for Carnival Cruise Lines, Inc. (see Table H.1). Fantasy, Ecstasy, and Sensation were delivered in 1990, 1991, and 1992. Fascination was delivered in 1994, and Imagination was delivered in 1995. Inspiration was delivered in 1996; the seventh, Elation, and the eighth, Paradise, were delivered in 1998. Each ship accommodates about 2,600 passengers, plus approximately 1,000 crew.

In addition, the cruise liner Grandeur of the Seas was delivered in 1996, and Enchantment of the Seas in 1997. These two were built for Royal Caribbean Cruises Ltd. Each accommodates about 2,400 passengers, plus about 800 crew, and has a gross tonnage of 74,000 tons and an overall length of 279.1 meters.³

²The Azipod propulsion unit, azimuthing through 360°, incorporates an electric AC motor located inside the propeller pod. The whole pod rotates, so the assembly produces vectored thrust, obviating the need for a rudder. The motor is driven by electric current generated by diesel engines. Eliminating the shaft results in a major design flexibility and space savings. A major breakthrough for the Azipod propulsion was the decision by Carnival Cruise Lines, Inc., to select Azipod propulsion for two 70,400 Fantasy-class cruise liners. Each of the cruise liners, due for delivery in 1998, will be fitted with two 14-megawatt Azipod units, which will result in useful space and weight savings on board, and will improve the ship's fuel efficiency.

³Between 1990 and 1996, Fincantieri, a rival builder of cruise ships, won orders for a total of 19 cruise vessels having an aggregate value of more than 10 trillion lire ($6.6 billion). When Walt Disney decided to enter the cruise business in spring 1995, it turned to Fincantieri to build its first ships, the 85,000-ton Disney Magic and Disney Wonder, each of which can carry 2,400 passengers. The Italian state shipbuilder has almost 40 percent of the total current world order-book for cruise ships, more than twice its nearest rival, Kvaerner Masa. Fincantieri has delivered the 101,000-gross-ton, $400M Carnival Destiny, the biggest cruise ship ever at the time, able to carry 3,300 holiday-
**Table H.1**

**Specifications of Eight Carnival Cruise Ships Being Built by Kvaerner Masa**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length overall</td>
<td>260.6 meters</td>
</tr>
<tr>
<td>Maximum beam</td>
<td>36.0 meters</td>
</tr>
<tr>
<td>Freeboard</td>
<td>53.6 meters</td>
</tr>
<tr>
<td>Draft</td>
<td>7.75 meters</td>
</tr>
<tr>
<td>Speed</td>
<td>22 knots</td>
</tr>
<tr>
<td>Gross tonnage</td>
<td>70,367 tons</td>
</tr>
</tbody>
</table>

NOTE: Tonnage definitions vary for different types of ships. For passenger ships, the term is gross tonnage; for tankers and bulk cargo ships, the term is deadweight tonnage; and for warships, the term is displacement tonnage. These are defined as follows:

- **Gross tonnage.** A measure of the total volume of enclosed spaces in the ship. The volume-to-tonnage conversion is 100 cu ft/ton.
- **Deadweight tonnage.** A measure of the total volume of the ship dedicated to carrying cargo, converted to tons of seawater (35 cu ft/ton).
- **Displacement tonnage.** The volume of water displaced by the hull beneath the waterline, converted to tons of seawater (35 cu ft/ton).

**CORE COMPETENCIES AT KVAERNER MASA**

Kvaerner Masa is one of the most innovative and profitable commercial shipyards in the world today, consistently returning a profit of 15 percent on net sales. Very competitive in the cruise-ship-construction niche as well as in other large, complex ship areas (liquid-natural-gas [LNG] carriers, icebreakers, cable ships), Kvaerner views itself as having four strengths:

- Project coordination
- Basic design of complex ships
- Hull fabrication
- Integration, final outfitting, and test.

**Project Coordination**

Each ship has a project manager and a deputy. The owner usually has representatives in the yard. One customer has a staff of 35 (similar to Supervisors of

Shipbuilding at U.S. shipyards); the other major owner has only one representative.

Corporate overhead functions are kept to a minimum. For example, administrative staff is a grand total of 5 (including one lawyer and one cost estimator); marketing has 10 people. All other people are in profit centers and are direct-charges.

**Basic Design of Complex Ships**

To build a new design, the first of a new class, Kvaerner would have a contract design specification of a few drawings and maybe 400 pages (compared with 2,000 drawings and many tomes for the United States). It would then take 3 years from beginning of design to delivery for a 70,000-ton cruise ship to be constructed, and 2 years and 3 months for the second.

The design office in Helsinki has 130 designers, 60 of whom are engineers from all disciplines. It has several architects working because of the emphasis on interior design. The architectural desires make the naval architects’ job very difficult: Large open spaces in the hull disrupt deck continuity and deprive the ship of its traditional source of longitudinal strength. Many large windows on the sides further rob bending strength. Nevertheless, designers are very customer-oriented and develop design solutions to customer demands.

**Hull Fabrication**

Construction of large, complex cruise ships requires significant facilities, such as graving docks, piers, heavy-lift cranes, and covered work areas for steel fabrication and erection. The facilities are optimized for a throughput of 25,000 tons of steel per year.

The yard has, for several years, worked with the mill that supplies the steel, so that the steel now comes cut to size, bent to shape, end-prepped for welding, and blasted and coated. The specifications are sent to the yard by computer. The steel throughput is about 20–25 thousand tons a year (a small part of the mill’s capacity). The steel-storage area in the yard is very small—maybe 100 plates of various sizes—because the yard demands just-in-time delivery on almost a daily basis. This approach allows Kvaerner to avoid making capital investments in facilities.

While visiting the yard, we saw several areas where steel-fabrication functions, automated in other yards, were being performed by a small group of workers. The production manager explained that the yard did not automate unless the process was a critical step in the time to complete the ship or if the yard could
prove that automation would result in savings. If task x could be performed by 8 people and timing was not critical, the return on investment for automating (and reducing manpower by, say, 50 percent, to 4) would not be there. Thus, the decision not to automate.

**Integration, Final Outfitting, and Test**

The company is very aggressive about outsourcing. At the moment, about 50–55 percent of the completed-ship cost is spent on contracts to buy parts and services from other entities that are better (and cheaper) at building and providing them than the yard. The key is to have a very clean, well-defined relationship with subcontractors and to avoid specifying to the contractor how to build something—not a new idea, of course, but one that Kvaerner has developed and is using very effectively.

Perhaps the best example of this approach is Kvaerner’s use of ready-to-install “floorless” modular cabins and bathroom units, which are manufactured by their Piikkiö Works, an independent profit center specializing in the manufacture of ready-to-install modular cabins and bathroom units for ships, offshore platforms, and hotels. The modular-cabin process and design are protected by patents. The cabins are delivered to the yard (Helsinki or Turku) by truck, three at a time. They are completely finished when delivered, including furniture, bathroom fixtures, carpet, and bed linen. It takes 10 man-hours to install each cabin. Helsinki needs about 2,200 cabins per year, so the production rate is quite high.

Kvaerner is considering expanding its outsourcing to buy more turnkey components, such as galleys, laundries, gambling rooms, and bridges. In many respects, Kvaerner Masa is an integrator of other people’s work. It has found that the less it does itself in the yard and the more it integrates, the more money is made and the more risk is reduced.

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4Piikkiö Works employs about 200 people and is located near the town of Turku. About 50 percent of Piikkiö Works’ production goes to competitors’ yards.